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Quarterly Report

No.11

LIFAC Sorbent Injection Desulfurization Demonstration Project

Presented By

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A Joint Venture Between

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Presented To

U.S. Department of Energy

Pittsburgh Energy Technology Center
Pittsburgh, Pennsylvania 15236

April - June 1993

LIFAC SORBENT INJECTION
DESULFURIZATION DEMONSTRATION PROJECT

QUARTERLY REPORT NO. 11

APRIL - JUNE 1993

Submitted to

U. S. DEPARTMENT OF ENERGY

by

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INTRODUCTION

In December 1990, the U.S. Department of Energy selected 13 projects for funding under the Federal Clean Coal Technology Program (Round III). One of the projects selected was the project sponsored by LIFAC North America, (LIFAC NA), titled "LIFAC Sorbent Injection Desulfurization Demonstration Project." The host site for this $22 million, three-phase project is Richmond Power and Light's Whitewater Valley Unit No. 2 in Richmond, Indiana. The LIFAC technology uses upper-furnace limestone injection with patented humidification of the flue gas to remove 75-85% of the sulfur dioxide (SO_2) in the flue gas.

In November 1990, after a ten (10) month negotiation period, LIFAC NA and the U.S. DOE entered into a Cooperative Agreement for the design, construction, and demonstration of the LIFAC system. This report is the eleventh Technical Progress Report covering the period April 1, 1993 through the end of June 1993. Due to the power plant's planned outage in March 1991, and the time needed for engineering, design and procurement of critical equipment, DOE and LIFAC NA agreed to execute the Design Phase of the project in August 1990, with DOE funding contingent upon final signing of the Cooperative Agreement.

BACKGROUND

Project Team

The LIFAC demonstration at Whitewater Valley Unit No. 2 is being conducted by LIFAC North America, a joint venture partnership between:

- <u>ICF Kaiser Engineers</u> - A U.S. company based in Oakland, California, and a subsidiary of ICF Kaiser International, Inc. (ICF) based in Fairfax, Virginia.

- <u>Tampella Power Corp.</u> - A U.S. subsidiary of a large diversified international company, Tampella Corp., based in Tampere, Finland and the original developer of the LIFAC technology.

LIFAC NA is responsible for the overall administration of the project and for providing the 50 percent matching funds. Except for project administration, however, most of the actual work is being performed by the two parent firms under service agreements with LIFAC NA. Both parent firms work closely with Richmond Power and Light and the other project team members, including ICF Resources, the Electric Power Research Institute (EPRI), Indiana Corporation for Science and Technology (ICS&T), and Black Beauty Coal Company. LIFAC NA is having ICF Kaiser Engineers manage the demonstration project out of its Pittsburgh office, which provides excellent access to the DOE representatives of the Pittsburgh Energy Technology Center. Figure 1 shows the management structure being used throughout the three phases of the project.

LIFAC NA administers the project through a Management Committee that decides the overall policies, budgets, and schedules. All funding sources, invoicing, and information flows to LIFAC NA where the managing partners ensure that the project, funding and expenditures are consistent and in-line with the established policies, budgets, schedules and procedures.

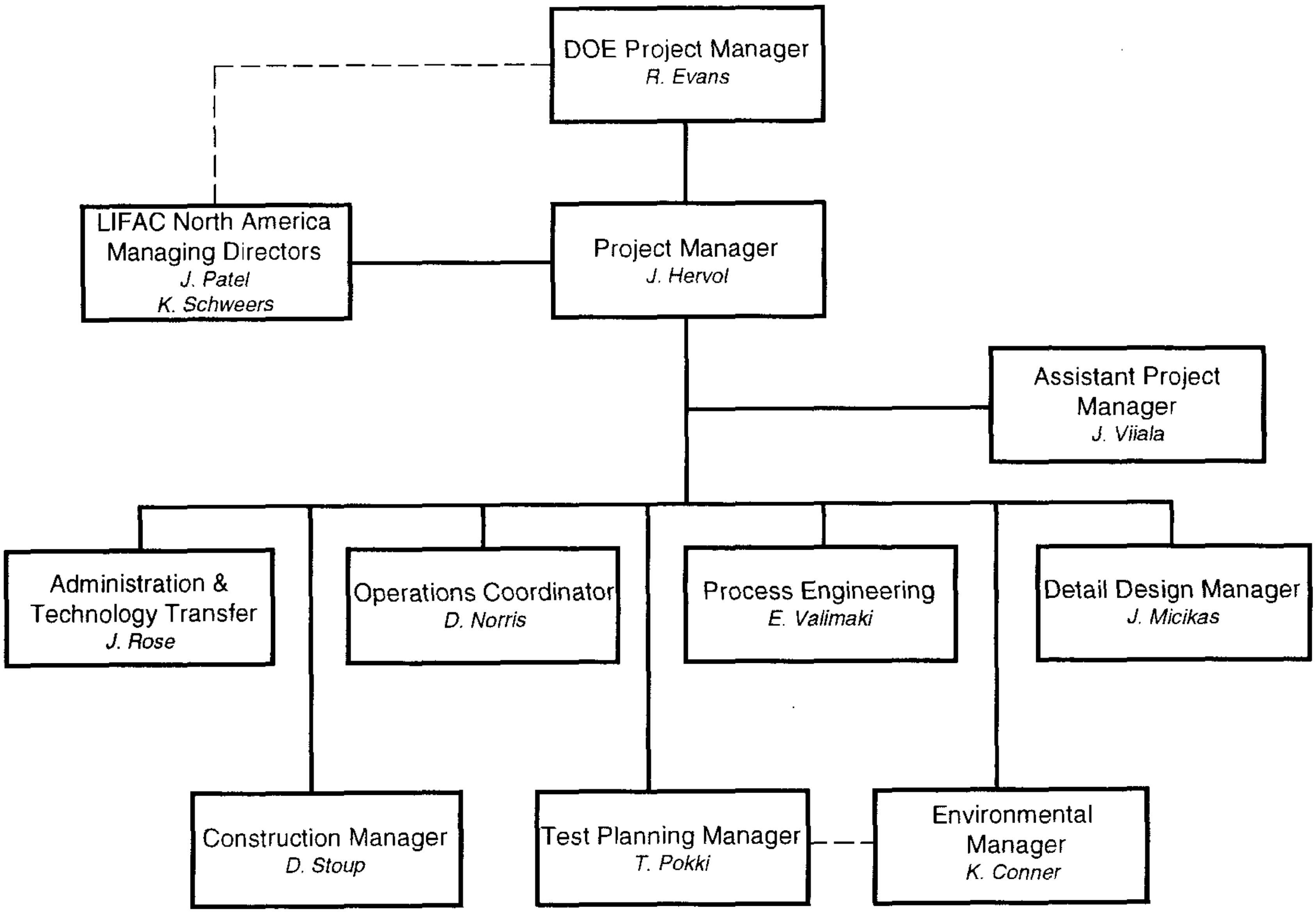
Process Development

In 1983, Finland enacted acid rain legislation which applied limits on SO_2 emissions sufficient to require that flue gas desulfurization systems have the capability to remove about eighty percent (80%) of the sulfur dioxide in the flue gas. This level could be met by conventional scrubbers, but could not be met by then available sorbent injection technology. Therefore, Tampella began developing an alternative system which resulted in the LIFAC process.

Initially, development included laboratory-scale and pilot-plant tests. Full-scale limestone injection tests were conducted at Tampella's Inkeroinen facility, a 160 MW coal-fired boiler using high-ash, low-sulfur Polish coal. At Ca:S ratios of 3:1, sulfur removal was less than 50%. Better results could have been attained using lime, but was rejected because the cost of lime is much higher than that of limestone.

In-house investigations by Tampella led to an alternative approach involving humidification in a separate vertical chamber which became known as the LIFAC Process. In cooperation with Pohjolan Voima Oy, a Finnish utility, Tampella installed a full-scale limestone injection facility on

Project Organization



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a 220 MW coal-fired boiler located at Kristiinankaupunki. At this facility, a slipstream (5000 SCFM) containing the calcined limestone was used to test a small-scale activation reactor (2.5 MW) in which the gas was humidified. Reactor residence times of 3 to 12 seconds resulted in SO_2 removal rates up to 84%. Additional LIFAC pilot-scale tests were conducted at the 8 MW (thermal) level at the Neste Kulloo combustion laboratory to develop the relationships between the important operating and design parameters. Polish low-sulfur coal was burned to achieve 84% SO_2 removal.

In 1986, full-scale testing of LIFAC was conducted at Imatran Voima's Inkoo power plant on a 250 MW utility boiler. An activation chamber was built to treat a flue gas stream representing about 70 MW. Even though the boiler was 250 MW, the 70 MW stream represented about one-half of the flue gas feeding one of the plant's two ESP's (i.e., each ESP receives a 125 MW gas stream). This boiler used a 1.5% sulfur coal and sulfur removal was initially 61%. By late 1987, SO_2 removal rates had improved to 76%. In 1988, a LIFAC activation reactor was added to treat an additional 125 MW -- i.e., an entire flue gas/ESP stream-worth of flue gas from this same boiler. This newer activation reactor is achieving 75-80% SO_2 removal with Ca:S ratios between 2:1 and 2.5:1. In 1988, the first tests using high-sulfur U.S. coals were run at the pilot scale at the Neste Kulloo Research Center, using a Pittsburgh No. 8 coal containing 3% sulfur. SO_2 removal rates of 77% were achieved at a Ca:S ratio of 2:1.

This LIFAC demonstration project will be conducted on a 60 MW boiler burning high-sulfur U.S. coals to demonstrate the commercial application of the LIFAC process to U.S. utilities.

Process Description

LIFAC combines upper-furnace limestone injection followed by post-furnace humidification in an activation reactor located between the air preheater and the ESP. The process produces a dry and stable waste product that is partially removed from the bottom of the activation reactor and partially removed at the ESP.

Finely pulverized limestone is pneumatically conveyed and injected into the upper part of the boiler. Since the temperatures at the point of injection are in the range of 1800-2000° F, the limestone ($CaCO_3$) decomposes to form lime (CaO). As the lime passes through the furnace, initial desulfurization reactions take place. A portion of the SO_2 reacts with the CaO to form calcium sulfite ($CaSO_3$), part of which then oxidizes to form calcium sulfate ($CaSO_4$). Essentially all of the sulfur trioxide (SO_3) reacts with the CaO to form $CaSO_4$.

The flue gas and unreacted lime exit the boiler and pass through the air preheater. On leaving the air preheater, the gas/lime mixture is directed to the patented LIFAC activation reactor. In the reactor, additional sulfur dioxide capture occurs after the flue gas is humidified with a water spray. Humidification converts lime (CaO) to hydrated lime, $Ca(OH)_2$, which enhances further SO_2 removal. The activation reactor is designed to allow time for effective humidification of the flue gas, activation of the lime, and reaction of the SO_2 with the sorbent. All the water droplets evaporate before the flue gas leaves the activation reactor. The activation reactor is also designed specifically to minimize the potential for solids build-up on the walls of the chamber. The net effect is that at a Ca:S ratio in the range of 2:1 to 2.5:1, 70-80% of the SO_2 is removed from the flue gas.

The flue gas leaving the activation reactor then enters the existing ESP where the spent sorbent and fly ash are removed from the flue gas and sent to the disposal facilities. ESP effectiveness is also enhanced by the humidification of the flue gas. The solids collected by the ESP consist of fly ash, $CaCO_3$, $Ca(OH)_2$, CaO, $CaSO_4$, and $CaSO_3$. To improve utilization of the calcium, and increase SO_2 reduction to between 75 and 85%, a portion of the spent sorbent collected in the bottom of the activation reactor and/or in the ESP hoppers is recycled back into the ductwork just ahead of the activation reactor.

Process Advantages

The LIFAC technology has similarities to other sorbent injection technologies using humidification, but employs a unique patented vertical reaction chamber located down-stream of the boiler to facilitate and control the sulfur capture and other chemical reactions. This chamber improves the overall reaction efficiency enough to allow the use of pulverized limestone rather than more expensive reagents such as lime which are often used to increase the efficiency of other sorbent injection processes.

Sorbent injection is a potentially important alternative to conventional wet lime and limestone scrubbing, and this project is another effort to test alternative sorbent injection approaches. In comparison to wet systems, LIFAC, with recirculation of the sorbent, removes less sulfur dioxide - 75-85% relative to 90% or greater for conventional scrubbers - and requires more reagent material. However, if the demonstration is successful, LIFAC will offer these important advantages over wet scrubbing systems:

- LIFAC is relatively easy to retrofit to an existing boiler and requires less area than conventional wet FGD systems.

- LIFAC is less expensive to install than conventional wet FGD processes.

- LIFAC's overall costs measured on a dollar-per-ton SO_2 removed basis are less, an important advantage in a regulatory regime with trading of emission allocations.

- LIFAC produces a dry, readily disposable waste by-product versus a wet product.

- LIFAC is relatively simple to operate.

HOST SITE DESCRIPTION

The site for the LIFAC demonstration is Richmond Power and Light's Whitewater Valley 2 pulverized coal-fired power station (60 MW), located in Richmond, Indiana. Whitewater Valley 2, which began service in 1971, is a Combustion Engineering tangentially-fired boiler which uses high-sulfur bituminous coal from Western Indiana. Actual power generation produced by the unit approaches 65 megawatts. As such, it is one of the smallest existing, tangentially-fired units in the United States. The furnace is 26-feet, 11-inches deep and 24-feet, 8-inches wide. It has a primary and secondary superheater. Tube sizes and spacings are designed to achieve the highest possible heat-transfer rates with the least potential for gas-side fouling. The unit also has an inherent low draft-loss characteristic because of the lack of gas turns. At full load 540,000 lbs/hr. of steam are generated. The heat input at rated capacity is 651 x 10^6 Btu per hour. The design superheater outlet pressure and temperature are 1320 psi at 955°F. The unit has a horizontal shaft basket-type air preheater. The temperature leaving the economizer is about 645°F, while the stack gas temperature is about 316°F. The balanced-draft unit has 12 burners.

In 1980 the unit was fitted and fully optimized with a state-of-the-art Low-NO_x Concentric Firing System (LNCFS). The LNCFS represents a very cost effective means of reducing NO_x emissions in comparison with other retrofit possibilities. The system works on the principal of directing secondary air along the sides of the furnace and creating a fuel rich zone in the center of the furnace. With the LNCFS, the excess air can be maintained below 20 percent. Additionally, the installation reduces ash accumulation on the furnace walls increasing heat absorption and reducing attemperation requirements. With the LNCFS, each corner of the furnace has a tangential windbox consisting of three coal compartments and four auxiliary air compartments. At full load with all three 593 RB pulverizers operating, primary transport air from the pulverizers amounts to 23 percent of the total combustion air. Pulverizer capacity is 26,400 lbs/hr. with 52 grind coal and 70 percent minus 200 mesh.

Whitewater Valley 2 has a Lodge Cottrell cold side precipitator which was erected with the boiler. The precipitator treats 227,000 actual cubic feet per minute of 316°F flue gas with 45,000 square feet of collection area. The unit has two mechanical fields and four electrical fields and achieves 99 percent removal efficiency (from 3.9 gr/ft^3 to 0.04 gr/ft^3). The ESP performance was optimized by Lodge Cottrell when Richmond Power and Light purchased new controllers in 1985.

Whitewater Valley Unit 2's overall efficiency of 87.47 percent at full load has shown little variation over the years. The unit's average heat rate is 10,280 Btu/Kwh. At 60 percent of full load, the unit's efficiency increases to 88.17 percent. The unit uses approximately 0.935 pounds of coal per Kwh and generates 8.51 pounds of steam per Kwh.

The primary emissions monitored at the station are SO_2 and opacity. SO_2 emissions are calculated based on the coal analysis and are limited to 6 lbs/MBtu. Opacity is monitored using an in-situ meter at the stack and is currently limited to 40 percent. Current SO_2 emissions for the unit are approximately 4 lbs/MBtu, while opacity at full load ranges from 15 to 20 percent. Opacity at low load (40MW) ranges from 3 to 5 percent. Limited testing was conducted in November of 1986 for NO_x emissions. Results from the test work indicated that NO_x emissions averaged 0.65 lbs/MBtu.

Whitewater Valley 2 has several important qualities as a LIFAC demonstration site. One of these is that Whitewater Valley 2 was the site of a prior joint EPA/EPRI demonstration of LIMB sorbent injection technology. Much of the sorbent injection equipment remains on site and is being used in the LIFAC demonstration. Another advantage of the site is that Whitewater Valley 2 was a challenging candidate for a retrofit due to the cramped conditions at the site. The plant is thus typical of many U.S. power plants which are potential sites for application of LIFAC. In addition, the Whitewater Valley 2 boiler is small relative to its capacity; hence, it has high-temperature profiles relative to other boilers. This situation requires sorbent injection at higher points in the furnace to minimize deadburning of the reagent, but it decreases residence times needed for sulfur removal. Whitewater Valley 2 will show LIFAC's performance under operational conditions most typical of U.S. power plants. The project will demonstrate LIFAC on high-sulfur U.S. coals and is a logical extension of the Finnish demonstration work and important for LIFAC's commercial success in the U.S.

PROJECT SCHEDULE

To demonstrate the technical viability of the LIFAC process to economically reduce sulfur emissions from the Whitewater Valley Unit No. 2, LIFAC NA is conducting a three-phase project.

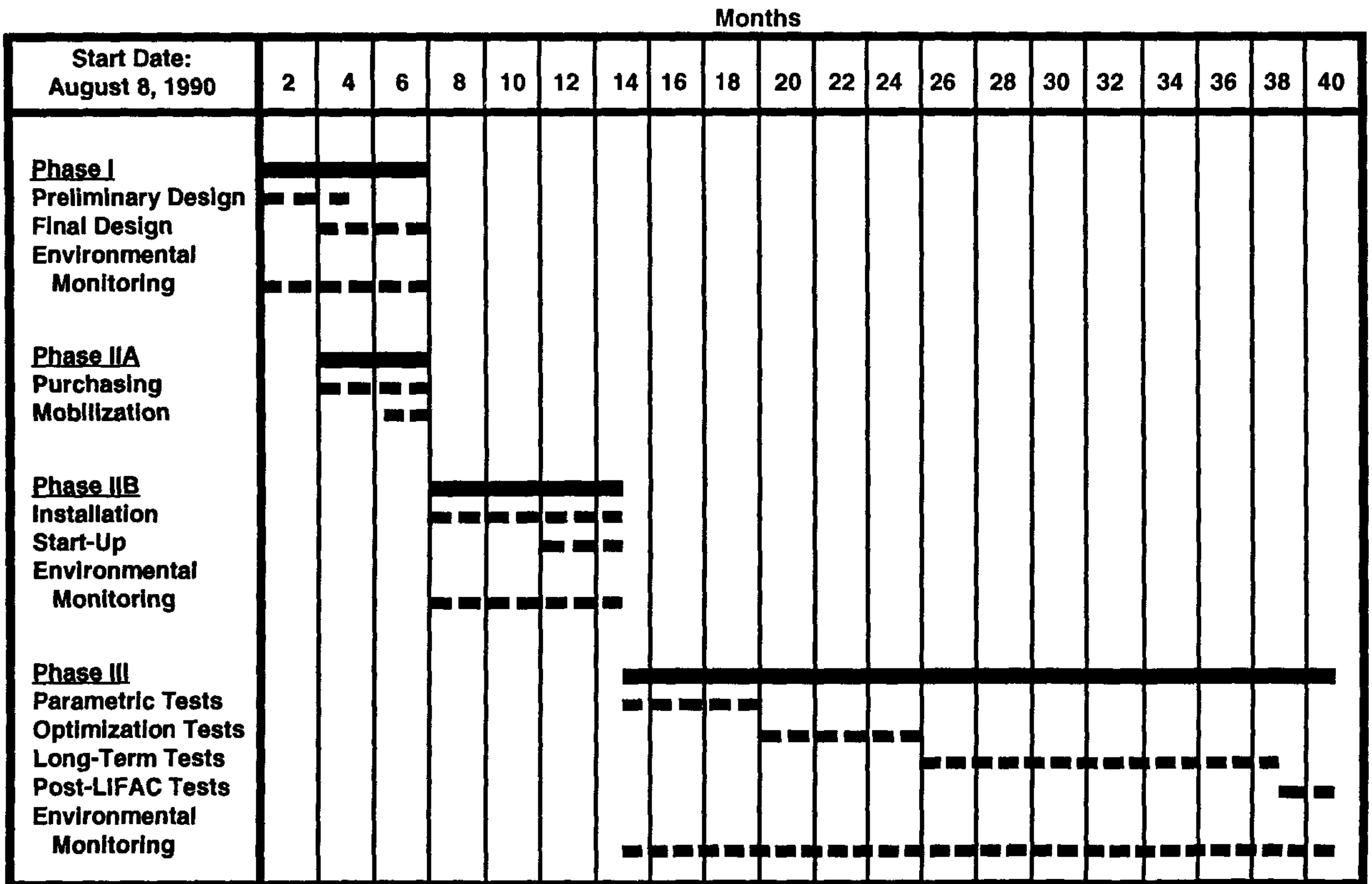
Phase I: **Design**
Phase IIA: **Long Lead Procurement**
Phase IIB: **Construction**
Phase III: **Operations**

Except Phase IIA, each phase is comprised of three (3) tasks, a management and administration task, a technical task and an environmental task. The design phase began on August 8, 1990 and was scheduled to last six (6) months. Phase IIA, long lead procurement, overlaps the design phase and was expected to require about four (4) months to complete. The construction phase was then to continue for another seven (7) months, while the operations phase was scheduled to last about twenty-six (26) months. Figure 2 shows the original estimated project schedule which is based on an August 8, 1990 start date and a planned outage of Whitewater Valley 2 during March 1991.

It is during this outage that all the tie-ins and modifications to existing Unit No. 2 equipment were made. This required that the construction phase begin in early February, 1991 -- construction was to be completed by the end of August 1991. Operations and testing were to begin in September 1991 and continue for 26 months. However, during previous reporting periods, the project encountered delays in receiving its construction permit. These delays, along with some design changes, and an approved expansion in project scope required that the Design Phase be extended by about eleven months. Therefore, construction was not completed until early June 1992. This represents a nine-month extension in the overall schedule. During the last half of 1992, problems were encountered during startup and commissioning of some of the LIFAC components and systems. These problems required the parametric tests to be delayed until the first quarter 1993 which subsequently required adjustments in the entire testing schedule. During the initial parametric tests conducted during the first quarter this year, problems were encountered with increased opacity levels. These problems (see previous quarterly report) forced an extension in the parametric test schedule. Due to these delays, an adjustment was made to the testing schedule this period (see Figure 3). These delays, however, will not impact the overall

LIFAC Demonstration

Original Project Schedule



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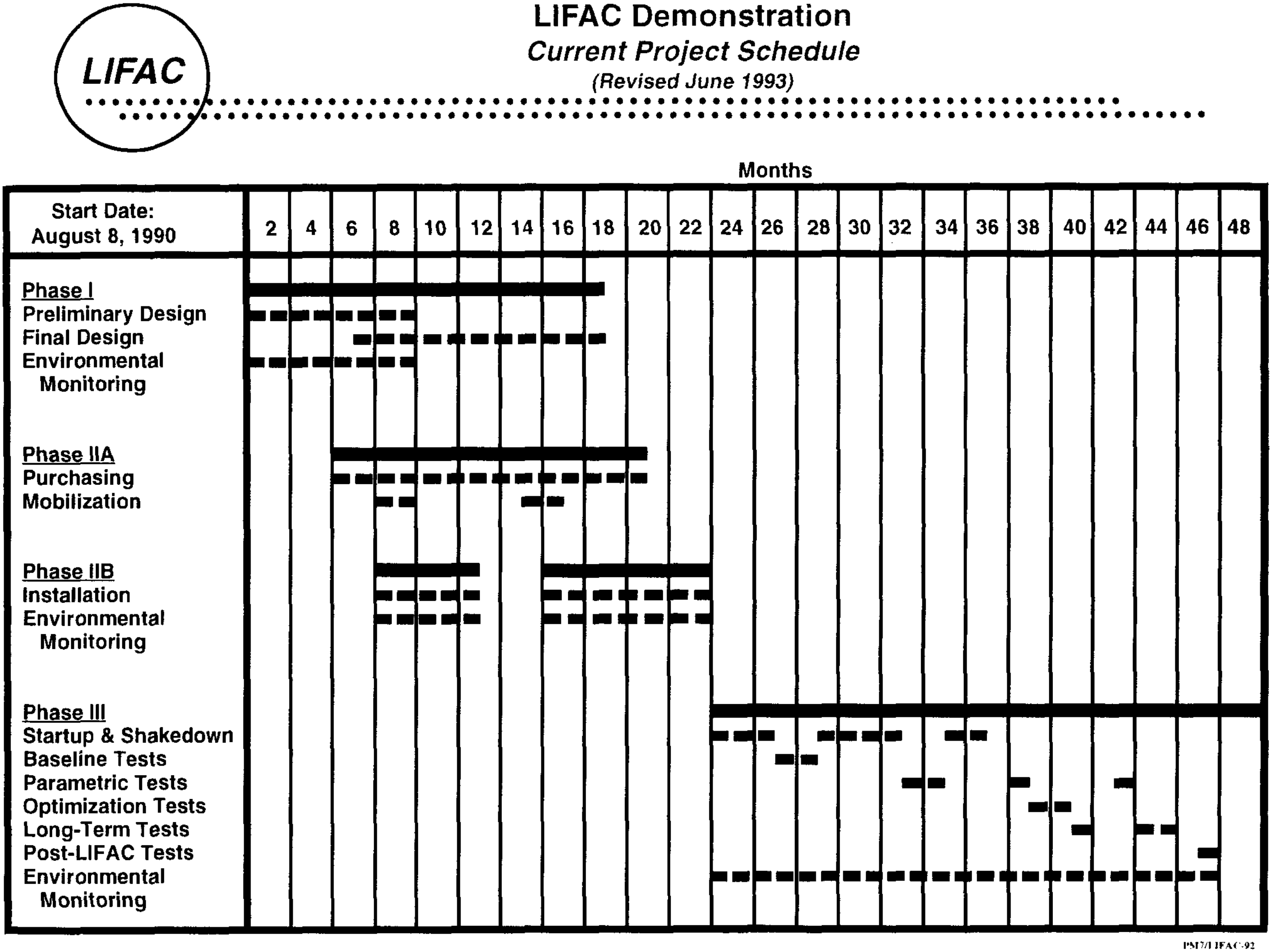
LIFAC Demonstration

Current Project Schedule

(Revised June 1993)



duration of the Operations Phase and the total project duration will remain at 48 months.

TECHNICAL PROGRESS

During this period (April - June) process parametric testing continued. EPRI and Southern Research Institute completed an extensive ESP performance test. Conference presentations were prepared for three upcoming symposiums in August and September. Process operations procedures were developed for continuous trouble-free LIFAC operation under various boiler loads and low particulate emissions.

Project Management (WBS 1.3.1)

During April through June 1993, management efforts and achievements included:

- **LIFAC Management Committee Meetings -** During the quarter, the Committee held one formal meeting on May 25 to discuss project status, problems, and potential solutions.

    - During this period some additional delays were encountered in the project schedule due to efforts to identify the root cause of increased opacity levels during initial LIFAC operations. By the end of the period, the testing effort had been re-established and a revised schedule approved by the Committee.

    - The budget/costs were reviewed with the Committee in light of the delays that occurred during the last few reporting periods. Although there have been delays, the expenditures are also behind schedule. Also, preliminary budgets were reviewed with the Committee for the two ESP upgrades.

- **Joint LIFAC NA - DOE Cooperation -** During this period, LIFAC NA continued to implement the Cooperative Agreement's management and administrative and technical provisions including DOE reporting and administrative requirements.

- LIFAC NA sent invoices to DOE during the period consistent with DOE requirements that the project report invoiced and committed costs on a phase-and-task basis.

- LIFAC NA management reviewed progress on the numerous periodic reports such as the Cost Management Report, the Financial Assistance Management Summary Report, Monthly Progress Report, Quarterly Reports, Milestone Status Reports, etc.

- **Regulatory** - LIFAC NA continues to monitor the negotiations between RP&L, IDEM, and EPA Region V. RP&L has requested a formal rule change in the SIP limits for TSP. The new proposed limits reflect actual day-to-day experience with the Whitewater Valley units. This process does not impact the demonstration project since LIFAC operates under a variance from the state. The current variance expired on June 30, 1993, however, IDEM granted the LIFAC project a one-year extension good until June 30, 1994.

- **Funding Agreements** - LIFAC NA concluded negotiations with the Electric Power Research Institute for its share of co-funding. EPRI has agreed to contribute up to $250,000. A portion of the EPRI funds was committed this period to study the effects of LIFAC on existing ESP performance. Future EPRI funding will be directed to measuring improvements in ESP performance as a result of the ESP upgrades and some trace element work.

- **Technology Transfer** - During this period, LIFAC NA prepared a technical paper for presentation at three technical conferences:

  - 1993 SO_2 Control Symposium, August 24-27, 1993
  - Second Annual Clean Coal Technology Conference, September 7-9, 1993
  - SO_2 Capture Seminar - "Sorbent Options and Considerations, September 19-21, 1993

Testing and Data Analysis (WBS 1.3.2)

Test Procedures - There were a total of fourteen test periods during this report period. During the month of June, test periods were conducted for longer continuous operations. The plant's boiler load varied according to power demands. Throughout these test periods, the process would be stopped periodically in order to attain baseline SO_2 levels. Coal samples were taken hourly and sulfur content was consistent at ~ 2.0%.

Parametric Testing

- Two limestone qualities were tested this period, 80% below 200 mesh and 80% below 325 mesh, both with high $CaCO_3$ content.

- A variety of limestone injection point combinations were also tested this period.

- The majority of the parametric tests conducted this period were performed with a calcium/sulfur molar ratio of 2:1; however, some higher and lower ratios were also tested.

- Various degrees of humidification were tested while varying the water droplet size (air pressure).

- ESP ash recycling tests were performed with a variety of rotary feeder speed settings ranging between 20% and 80% of full speed.

Testing Results

- Total SO_2 capture during testing ranged between 70% and 80%.

- There appears to be various degrees of sulfur capture in the boiler by varying the limestone injection location, however it appears to have very little impact on total sulfur capture.

- SO_2 capture in the boiler ranged between 20-25%, while the capture in the reactor ranged between an additional 45-60 percentage points. The highest capture rates occurred with high degrees of humidification or the closer the reactor outlet temperature was to saturation.

- Recycling ESP ash improved SO_2 capture by as much as 15-20%.

During this quarter, minor mechanical problems continue to surface in the three main areas.

Limestone Handling and Storage Area

- The VFD was put into service after RP&L's spring outage and failed again. All internal electrical components have been replaced, and the control module has been sent back to the vendor for further evaluation.

- The limestone injection hoses continue to wear and are scheduled to be hard-piped early next quarter.

- One of the three compressors has been consuming oil and will be serviced in July.

- The VFD room HVAC system failed; parts are on order and repairs should be complete by August.

Boilerhouse and ESP Area

- The flue gas analyzers continue their erratic operating characteristics. A service representative is again scheduled to visit the site during operations in August.

- The ESP ash recycle rotary valves were leaking and had to be sealed.

- The process computer program required minor modifications and component replacement.

Reactor Area

- The transfer conveyor was shearing pins at the drive sprocket assembly; the automatic drag chain tensioning device was set up improperly and after fine adjustments, is working properly.

- A pneumatic winch was installed to assist moving the ash dumpsters.

- The water control valve will not respond accurately to automatic control and will be replaced by a pneumatic fisher control valve during the next period.

- Humidification nozzle scraper assemblies have been shearing dowel roll pins and were being repaired at the end of the reporting period.

Environmental Monitoring (WBS 1.3.3)

Due to problems encountered during the last two reporting periods, no formal environmental monitoring activities occurred in the field this period. However, a draft final report was prepared of the Compliance and Supplemental Monitoring that occurred during baseline testing. The report will be reviewed internally and submitted to DOE next reporting period. Environmental monitoring will be re-initiated once parametric testing has been resumed.

FUTURE PLANS

- Submit the Baseline Environmental Report.
- Engineer two improvements for enhancing ESP performance; 1) revised reheat system; and 2) improved flue gas distribution system across the precipitator.
- Continue to make any necessary electrical or mechanical repairs to the LIFAC system to maintain or improve process availability.
- Continue parametric testing and operate process for longer, continuous periods.
- Present three technical conference presentations.
- Resume environmental monitoring.